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A preliminary simulation of dust load over Green Sahara in Mid-Holocene period with prescribed vegetation covers

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INTRODUCTION

A Green Sahara, instead of present desert Sahara, existed in North Africa during the early- to Mid-Holocene (11,000 to 5,000 years before present) as suggested by comprehensive paleoproxy data and studies.

Several factors are considered to play a role in establishing such a Green Sahara in a cause-effect or a coupled way. For example, the summer insolation in the Northern Hemisphere was larger than today due to the precession of the Earth, which resulted in a stronger West African Monsoon (WAM) and a northward West African rain belt. As a consequence, more vegetation were able to grow and more lakes appeared, which induce more precipitation and could further enhance WAM.

These coupled and complex processes have already been simulated by different models. On the basis of previous model works we aim to provide a more comprehensive simulation of the Mid-Holocene period with focus on the Green Sahara area, which can provide a reliable paleoclimate to help study how human beings migrated during the Holocene.

As a start, we simulated the global dust load with different prescribed vegetation covers according to Lu et al. (2018), representing pre-industrial vegetation (PI), Mid-Holocene vegetation forced by insolation and greenhouse gas concentration of 6000 years before present (6 ka BP) with pre-industrial vegetation and dust concentration (MH), and with prescribed Green Sahara vegetation and reduced dust concentration (MH_gsrd).

DUST LOAD

In this study we used TM5-MP (the global chemistry Transport Model version 5 – Massively Parallel version, or Tracer Model 5; Williams et al., 2017) to simulate the emissions, transportation, and depositions of dust globally with the meteorology conditions of Feb, 2009. The dust emission parameters in TM5-MP were modified according to the prescribed vegetation covers for MH, MH_gsrd in Saraha area (20ºW-40ºE, 10ºN-30ºN). For example, the potential sources of dust from paleolakes in MH and MH_gsrd were removed, the area with bare soil was considered as desert, the cultivation fraction was set to 0. The parameters in PI were not modified except that the cultivation fraction was also set to 0 for comparison. It should be noted that the dust can still be emitted from the surface with vegetation cover, which depends on the coverage and vegetation type.

The dust load in MH and MH_gsrd is nearly the same due to the current rough dust parameterization method in the model (Fig. 2). However, the difference between MH_gsrd and PI is apparent, especially in the west Sahara region (10ºW-20ºE, 5ºN-20ºN). The maximum dust load in PI is about 1.4 g m^{-2} while it is only 0.7 g m^{-2} in MH_gsrd. The total dust load in the west Sahara region in MH_gsrd has decreased by about 45% compared to PI.

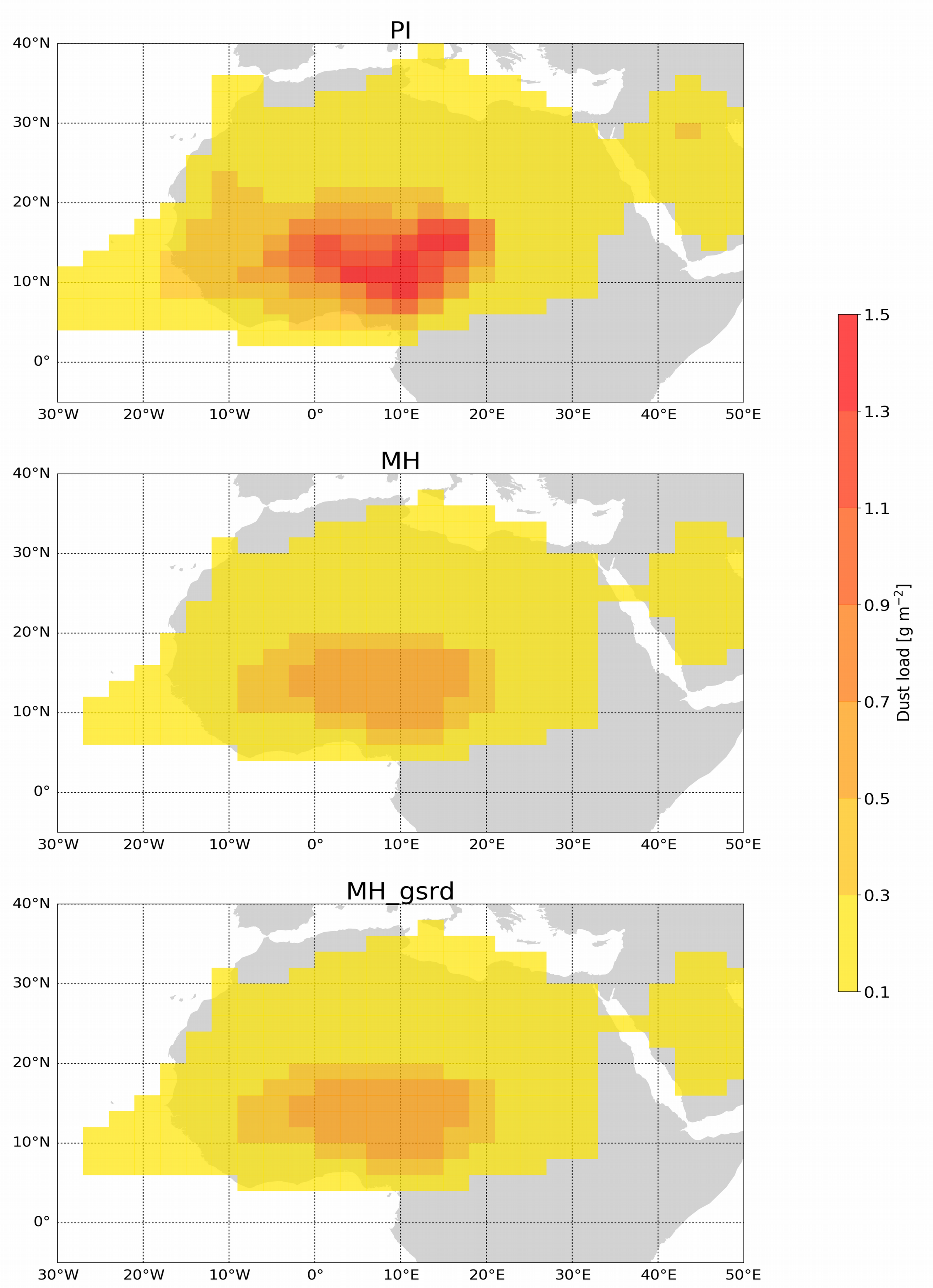

Figure 2: Simulated dust load in North Africa for three cases PI, MH, and MH_gsrd. Dust load is the sum of the dust mass through the whole model column.

VEGETATION COVER

The prescribed vegetation covers were obtained from LPJ-GUESS (Lund-Potsdam-Jena General Ecosystem Simulator; a dynamic global vegetation model; Smith et al., 2001) simulations which were forced by the climate from EC-Earth (A European community Earth-System Model;). The parameters used in the EC-Earth simulations for three cases are shown in Table 1 (Table S1, Lu et al., 2018).

EC-Earth Simulation	Orbital forcing	Green House Gases	Saharan vegetation	Saharan dust
PI	1850	PI	desert	PI
MH	6 ka BP	MH	desert	PI
MH_gsrd	6 ka BP	MH	shrub	Reduced

Compared to the case PI, the high vegetation moves northward to 20ºN in MH and nearly covers all of the North Africa in MH_gsrd. The low vegetation shows similar patterns with high vegetation but its peak regions are more limited, e.g., the area with vegetation cover larger than 0.2 is around 10ºN in PI, for MH it lies between 10ºN and 20ºN sporadically, while in the case MH_gsrd the peak region extends from 10ºN to 25ºN in the western North Africa (Fig. 1).

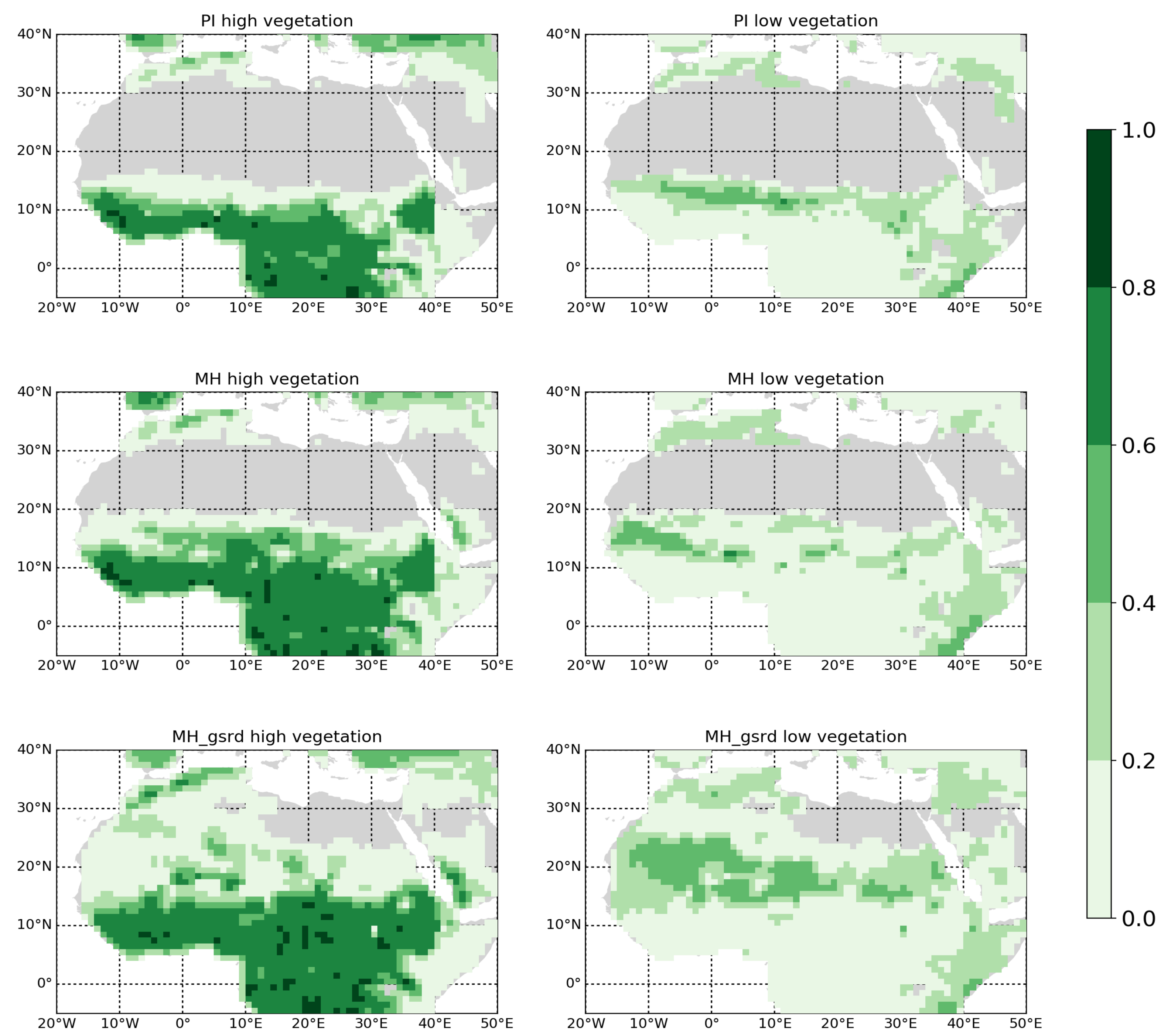

Figure 1: Prescribed vegetation cover obtained from LPJ-GUESS simulations in Lu et al. (2018). High vegetation types includes evergreen needleleaf trees, deciduous needleleaf trees, deciduous broadleaf trees, evergreen broadleaf trees, and mixed forest/woodland. Low vegetation types include short grass, tall grass, tundra, and bogs and marshes. The area with the sum of high and low vegetation smaller than 0.2 is considered as bare soil which is not plotted.

OUTLOOK

With different prescribed vegetation covers, the model is able to simulate resonable dust emissions which are smaller in MH and MH_gsrd with larger vegetation coverage in the Sahara region. In future we will continue this preliminary work as shown below:
1. Improving the dust model in TM5-MP.
2. Simulating dust emissions with more realistic meteorological conditions and with longer time.
3. Comparing our results with observations, e.g., measured dust concentrations at the surface, observed AOD (aerosol optical depth) at surface or from the satellite retrieval datasets, etc.
4. Simulating the whole Earth system with coupled EC-Earth for Green Sahara during Mid-Holocene period, and comparing the results with proxy data.

REFERENCE

Lu et al., 2018, GRL. Smith et al., 2001, Global Ecology & Biogeography. Hazeleger et al., 2010, BAMS. Williams et al., 2017, GMD.

ACKNOWLEDGEMENTS

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